US006803545B2

(12) **United States Patent**
Blake et al.

(10) **Patent No.: US 6,803,545 B2**
(45) **Date of Patent: Oct. 12, 2004**

(54) **ELECTRICALLY HEATED SMOKING SYSTEM AND METHODS FOR SUPPLYING ELECTRICAL POWER FROM A LITHIUM ION POWER SOURCE**

(75) Inventors: **Clinton E. Blake**, Mechanicsville, VA (US); **John R. Hairfield, Jr.**, Chester, VA (US); **Charles T. Higgins**, Richmond, VA (US); **H. Neal Nunnally**, Richmond, VA (US); **Robert L. Ripley**, Midlothian, VA (US)

(73) Assignee: **Philip Morris Incorporated**, Richmond, VA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 220 days.

(21) Appl. No.: **10/161,639**

(22) Filed: **Jun. 5, 2002**

(65) **Prior Publication Data**

US 2003/0226837 A1 Dec. 11, 2003

(51) **Int. Cl.**[7] **H05B 3/58**

(52) **U.S. Cl.** **219/268**; 219/535; 219/492; 131/194

(58) **Field of Search** 219/268, 262, 219/263, 260, 269, 492, 535; 131/194, 195

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,028,500 A		7/1991	Fong et al.		
5,060,671 A		10/1991	Counts et al.		
5,144,962 A	*	9/1992	Counts et al.	....	131/194
5,342,711 A		8/1994	Tamura et al.		
5,388,594 A	*	2/1995	Counts et al.	....	131/329
5,498,855 A	*	3/1996	Deevi et al.	....	219/553
5,499,636 A		3/1996	Baggett et al.		
5,505,214 A		4/1996	Collins et al.		
5,591,368 A	*	1/1997	Fleischhauer et al.	......	219/535
5,665,262 A	*	9/1997	Hajaligol et al.	....	219/553
5,934,289 A		8/1999	Watkins et al.		
5,981,107 A		11/1999	Hamano et al.		
6,040,560 A	*	3/2000	Fleischhauer et al.	......	219/494
6,246,217 B1		6/2001	Yoshida et al.		

FOREIGN PATENT DOCUMENTS

JP	2-100286	*	4/1990
JP	10-51962 A		2/1998
JP	10-285813 A		10/1998
JP	2002-240341	*	8/2002

OTHER PUBLICATIONS

PANASONIC, Overview of Lithium Ion Batteries, Jan. 2000, pp. 1–11.

PANASONIC, Battery Packs, Nickel Metal Hrdride Handbook, Jul. 2001, pp. 42–46.

TYCO/ Electronics, Raychem Circuit Protection, PolySwitch Resettable devices, Short–Form Catalog, Nov. 2001, pp. 1–12.

Notification of Transmittal of International Preliminary Examination Report dated Apr. 19, 2004 for PCT/US03/15997.

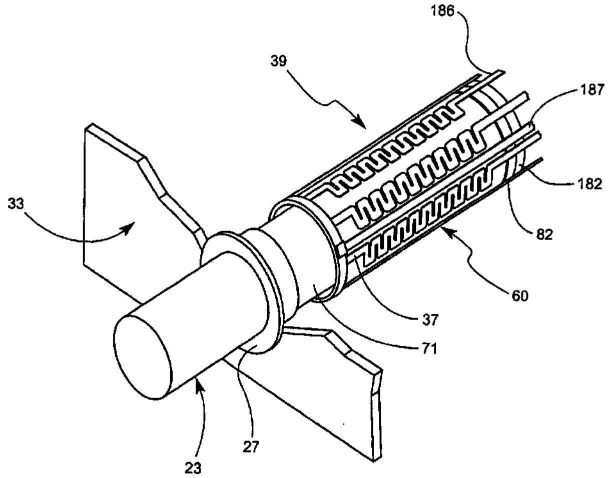
* cited by examiner

Primary Examiner—John A. Jeffery
(74) *Attorney, Agent, or Firm*—Burns, Doane, Swecker & Mathis, LLP

(57) **ABSTRACT**

An electrically heating smoking system wherein tobacco smoke is generated by heating a portion of a cigarette with an electrical resistance heating element powered by lithium ion battery cells. The lithium ion battery cells supply current to the electrical resistance heating element with current up to 20 times greater than the recommended discharge rate. To prevent damage to the lithium ion battery cells under such high discharge conditions, the smoking system includes a controller which provides modulated pulses of electrical power from the battery cells to the resistance heating element during smoking of the cigarette.

25 Claims, 4 Drawing Sheets



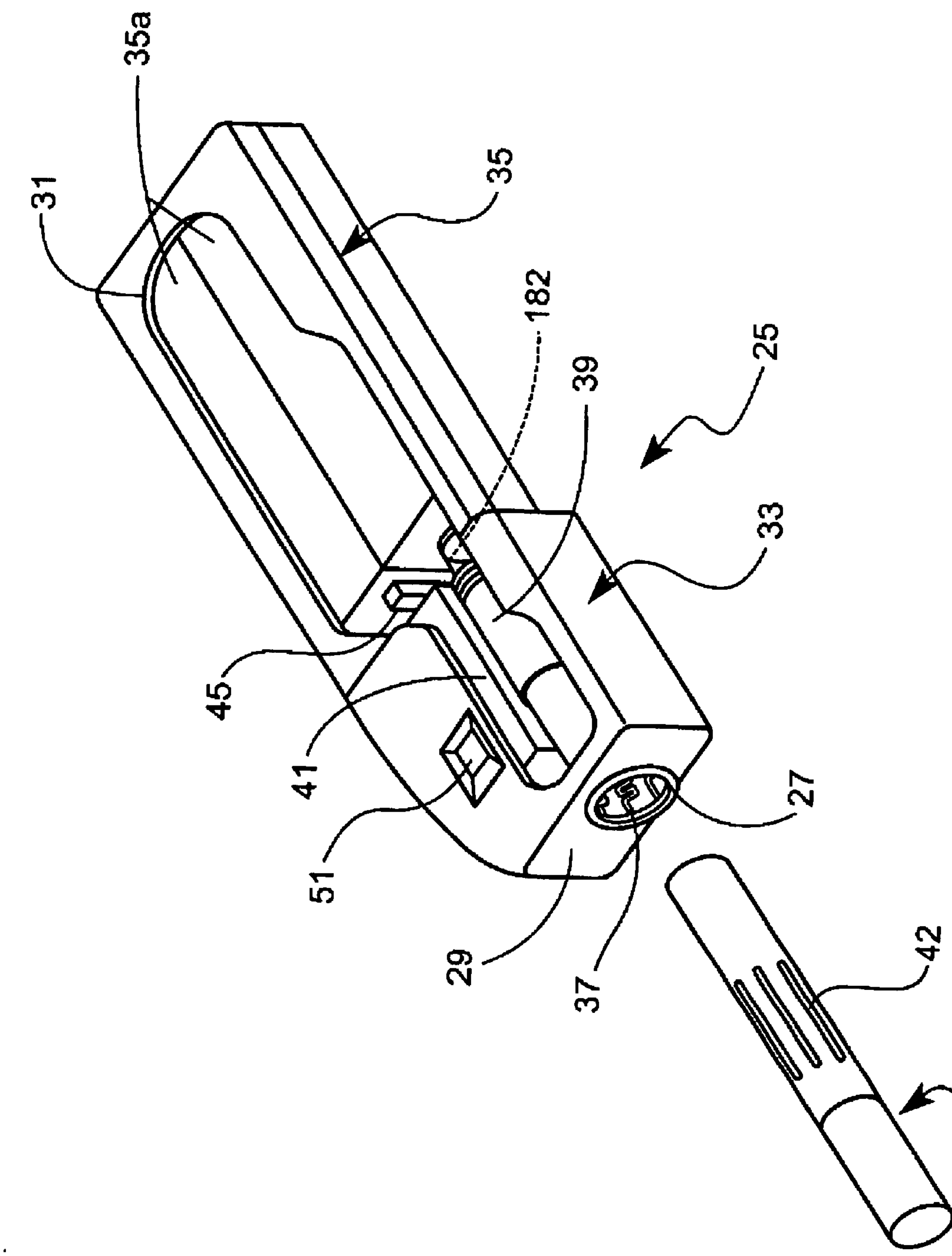


FIG. 1

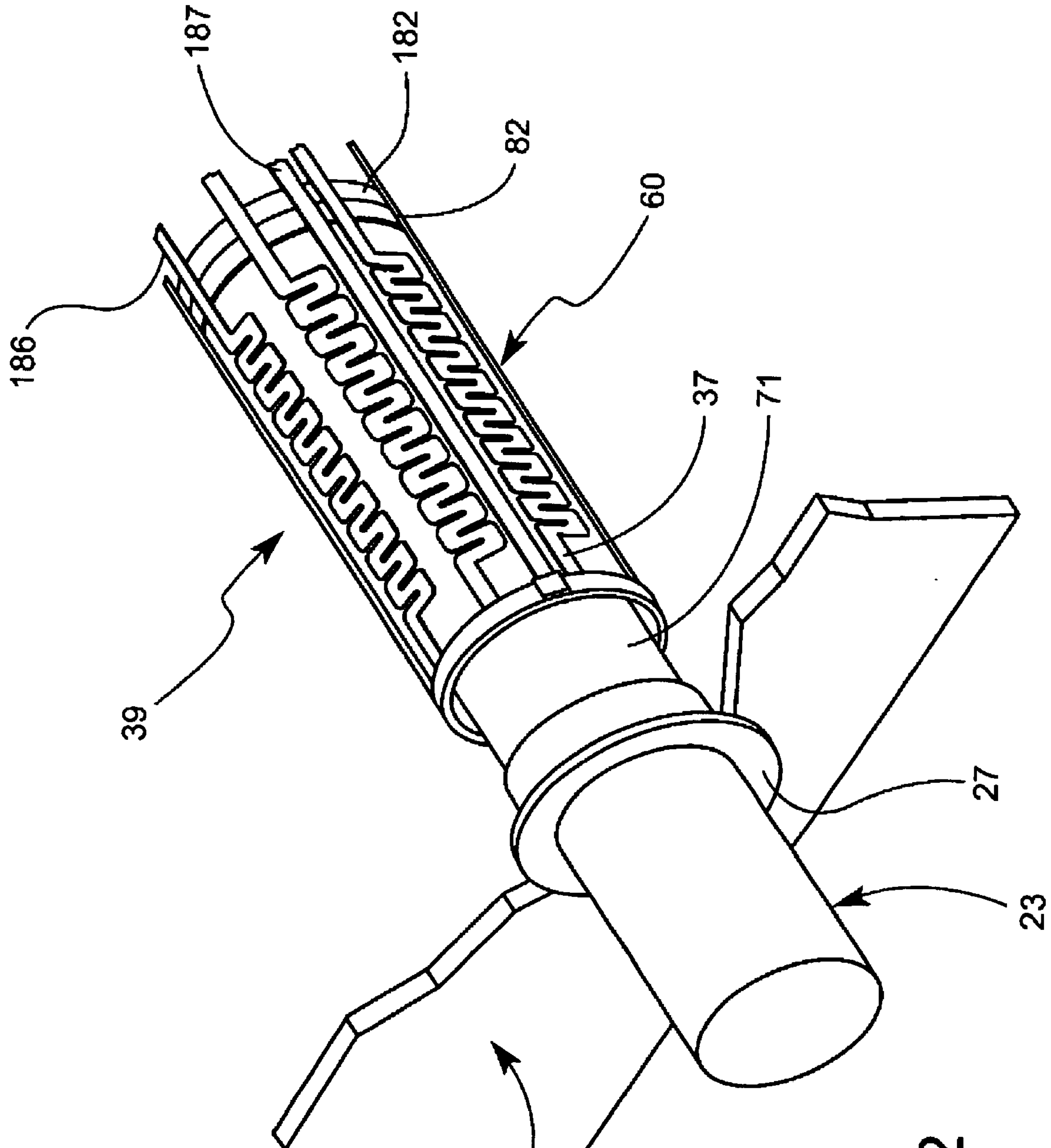


FIG. 2

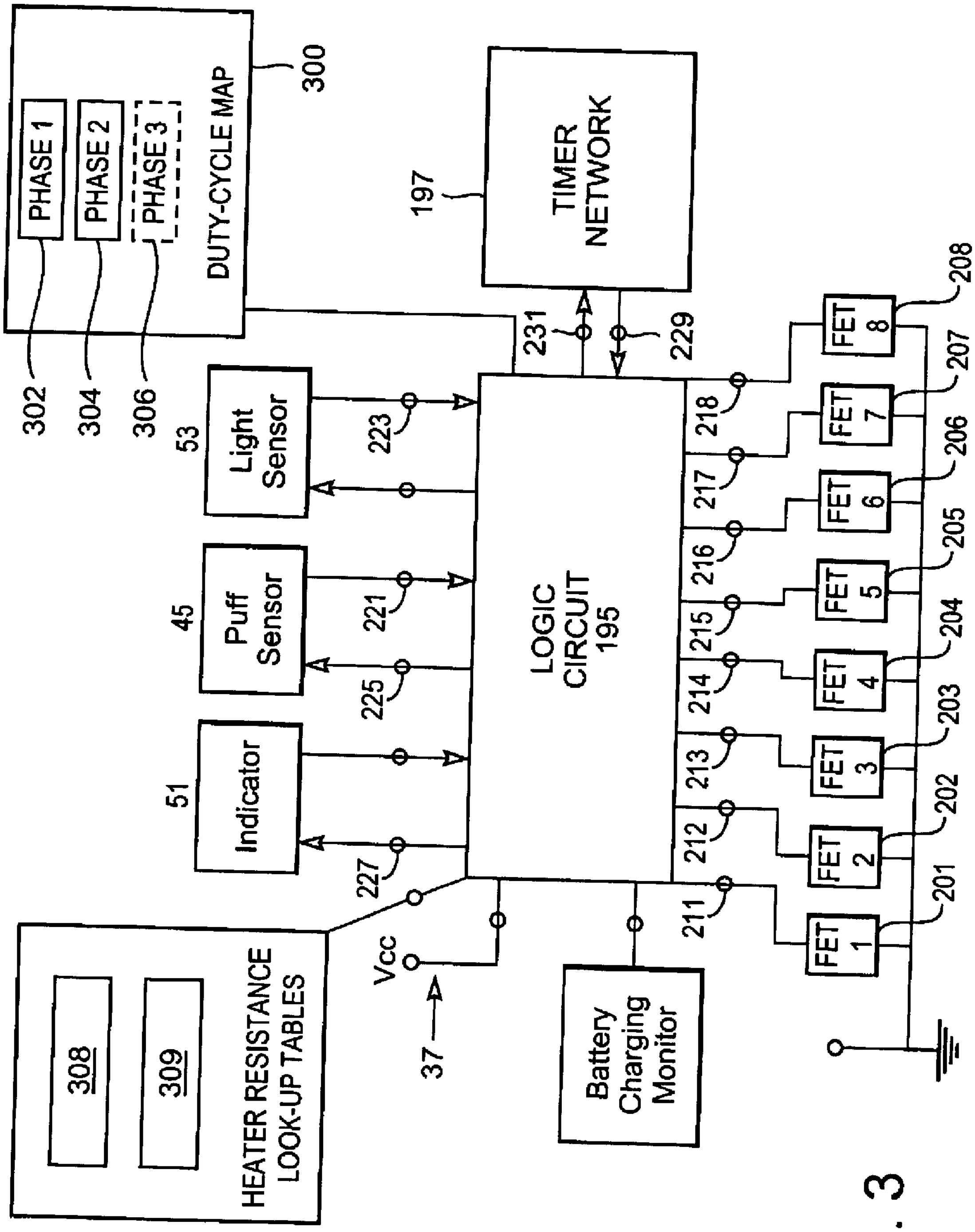

PHASE 1
PHASE 2
PHASE 3
DUTY-CYCLE MAP
300
302
304
306
TIMER NETWORK
197
231
229
Light Sensor
53
223
Puff Sensor
45
221
225
Indicator
51
227
LOGIC CIRCUIT 195
211
212
213
214
215
216
217
218
FET 1
FET 2
FET 3
FET 4
FET 5
FET 6
FET 7
FET 8
201
202
203
204
205
206
207
208
HEATER RESISTANCE LOOK-UP TABLES
308
309
Vcc
37
Battery Charging Monitor

FIG. 3

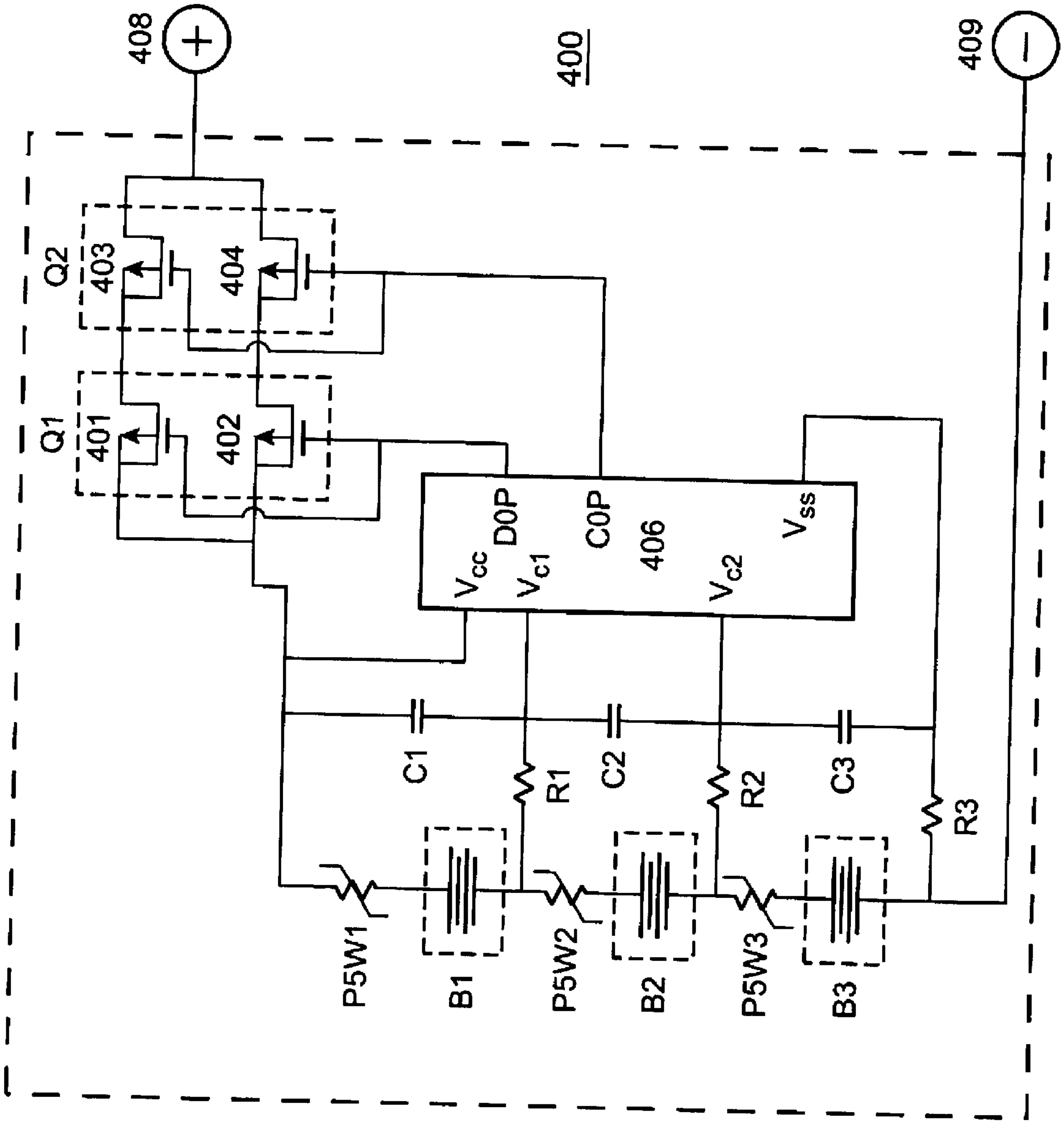

408
409
400
Q2
403
404
Q1
401
402
V_{cc}
D0P
V_{c1}
C0P
406
V_{c2}
V_{ss}
C1
R1
C2
R2
C3
R3
P5W1
B1
P5W2
B2
P5W3
B3

FIG. 4

ELECTRICALLY HEATED SMOKING SYSTEM AND METHODS FOR SUPPLYING ELECTRICAL POWER FROM A LITHIUM ION POWER SOURCE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to electrically heated smoking devices, and particularly to systems and methods for supplying electrical power to the electrically heated smoking devices from a lithium ion power source.

2. Description of Related Art

Lithium ion battery technology was introduced in the mid-nineteen nineties. Lithium ion batteries are rechargeable and do not exhibit memory effect which is common in other rechargeable batteries. Memory effect is a condition that occurs in some rechargeable batteries when the battery is not fully discharged before recharging. The battery remembers the amount of energy remaining in the battery at the time it was charged and will not discharge below that point. The result of the memory effect is that the energy storage capacity of the battery is reduced. Other significant advantages of lithium ion batteries are that they are lightweight, have a high energy storage capacity and higher voltage per cell than other batteries. This makes for a battery that is useful in small portable electronic equipment, e.g., wireless mobile telephones and notebook computers.

Due to the unique chemical structure and chemical reaction of lithium ion batteries, the batteries can be dangerous if over discharged or overcharged. Over discharging and overcharging of lithium ion batteries can cause an abundance of heat to be generated by the chemical reaction occurring in the battery. This abundance of heat can cause the lithium ion battery to become hot, catch fire or, explode. For this reason, circuitry is built into the lithium ion battery to monitor the temperature, voltage, and current drain of the battery. This circuitry will cut off power supplied by the lithium ion battery if the current drawn from the battery rises above a threshold level or the lithium ion battery voltage falls below a threshold level. The circuitry will also cut off power supplied to the lithium ion battery during charging if the voltage of the battery rises above a threshold level. Circuitry may also be included in the charger or a device connected to the battery to monitor charging and discharging of the lithium ion battery. This circuitry is required for each cell of a lithium ion battery adding to the cost of lithium ion batteries.

Lithium ion batteries are ideally suited for portable electronic equipment due to their small size and high energy densities. Portable electronic equipment generally draws relatively low current for sustained periods of time. Lithium ion batteries are not suitable for other portable equipment, e.g., cordless power tools, because these devices require a great amount of current when performing work, e.g., driving a screw with a cordless electric power drill. The required current would exceed the amount that lithium ion batteries can safely deliver creating a risk that the battery could become hot, catch fire, or explode.

The present invention provides an electrically heated smoking system which utilizes lithium ion batteries in a manner which allows high current to be delivered safely to the electrical resistance heating element during smoking of a cigarette.

BRIEF SUMMARY OF THE INVENTION

The invention provides an electrical heated smoking system having a heater including at least one electrical resistance heating element wherein a lithium ion power source is electrically connected to the at least one electrical resistance heating element and a controller controls a flow of modulated pulses of electrical power from the lithium ion power source to the at least one electrical resistance heating element to prevent damage to the lithium ion power source.

The invention also provides a method for supplying electrical power to at least one electrical resistance heating element from a lithium ion power source and controlling the electrical power provided to the at least one electrical heating element by sending modulated pulses of electrical power from the lithium ion power source to the at least one electrical heating element thereby preventing damage to the lithium ion power source.

BRIEF DESCRIPTION OF THE DRAWINGS

Various features of the invention will be described in the following detailed description in conjunction with the drawings, in which:

FIG. **1** is an isometric cut-away view of an electrically heated smoking device according to an embodiment of the invention.

FIG. **2** is an isometric view of a plurality of electrical resistance heaters according to an embodiment of the invention.

FIG. **3** is a schematic view of an electronic controller used in the electrically heated smoking device according to an embodiment of the invention.

FIG. **4** is a schematic view of a control circuit and lithium ion power source used in the electrically heated smoking device according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

In the following description, for purposes of explanation and not limitation, specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be apparent to one skilled in the art that the present invention may be practiced in other embodiments that depart from these specific details. In other instances, detailed descriptions of well known methods, devices, and circuits are omitted so as not to obscure the description of the present invention.

The present invention relates to an electrically heated smoking system. An exemplary electrically heated smoking system is disclosed in U.S. Pat. No. 6,040,560 issued to Fleischhauer et al which is hereby incorporated by reference. The disclosed electrically heated smoking system heats a portion of a cigarette with one or more electrical resistance heating element(s). A heated portion of the cigarette generates tobacco smoke that is delivered to the smoker when a smoker puffs on the cigarette. Electrical energy is supplied to the electrical resistance heating element from one or more nickel cadmium batteries. Nickel cadmium batteries have sufficient discharge capacity to deliver the large amount of current required by the electrical resistance heating element to rapidly heat a portion of a cigarette. Nickel cadmium batteries are also safe, rechargeable and relatively inexpensive.

While nickel cadmium batteries have been effective for use in electrically heated smoking systems, they are not without disadvantages. For example, nickel cadmium batteries suffer from memory effect. As discussed above, memory effect prevents a battery from fully discharging when the battery is not fully, or nearly fully, discharged prior to charging. This results in a decline in the storage capacity of the battery. When a nickel cadmium battery suffering from memory effect is used in an electrically heated smoking system, the battery requires more frequent recharging due to the reduced storage capacity. In addition, nickel cadmium batteries are relatively heavy, large and produce low voltage per cell.

Referring to FIG. **1**, a preferred embodiment of the present invention provides a smoking system which preferably includes a cigarette **23** and a reusable lighter **25**. The cigarette **23** is adapted to be inserted into and removed from a receptacle **27** at a front end portion **29** of the lighter **25**. Once the cigarette **23** is inserted, the smoking system **21** is used in much the same fashion as a more traditional cigarette, but without lighting or smoldering of the cigarette **23**. The cigarette **23** is discarded after one or more puff cycles. Preferably, each cigarette **23** provides a total of 8 puffs (puff cycles) or more per smoke; however, it is a matter of design expedient to adjust to a lesser or greater total number of available puffs.

The smoking system is described in greater detail in commonly assigned U.S. Pat. No. 5,388,594 which is hereby incorporated by reference in its entirety. The cigarette **23** is further described in commonly assigned U.S. Pat. No. 5,499,636, which is hereby incorporated by reference in its entirety.

The lighter **25** includes a housing **31** having front and rear housing portions **33** and **35**. One or more batteries **35***a* are removably located within the rear housing portion **35** and supply energy to one or more electrical resistance heating element(s) **37** which are arranged within the front housing portion **33** adjacent the receptacle **27**. A control circuit **41** in the front housing portion **33** establishes electrical communication between the batteries **35***a* and the electrical resistance heater elements **37**. A preferred embodiment of the present invention includes details concerning the control circuit **41** and lithium ion power source **35***a* which are discussed in greater detail beginning with reference to FIG. **3**.

Still referring to FIG. **1**, preferably the rear portion **35** of the lighter housing **31** is adapted to be readily opened and closed, such as with screws or snap fit components, so as to facilitate replacement of the lithium ion power source **35***a*. An electrical socket or contacts may be provided for recharging the lithium ion power source **35***a* in a manner known to one skilled in the art.

The one or more batteries **35***a* are sized to provide sufficient power for the heaters **37** to function as intended and comprises a rechargeable lithium ion power source. The characteristics of the lithium ion power source are, however, selected in view of the characteristics of other components in the smoking system **21**, particularly the characteristics of the heating elements **37**. Commonly assigned U.S. Pat. No. 5,144,962, hereby incorporated by reference, describes a power arrangement which comprises a battery and a capacitor. The capacitor is recharged by the battery and power stored in the capacitor is used to supply electrical energy to the electrical resistance heating element.

Still referring to FIG. **1**, preferably, the circuitry **41** is activated by a puff-actuated sensor **45** that is sensitive to either changes in pressure or changes in rate of airflow that occur upon initiation of draw on the cigarette **23** by a smoker. The puff-actuated sensor **45** is preferably located within the front housing portion **33** of the lighter **25** and is communicated with a space inside the heater fixture **39** adjacent the cigarette **23** through a passageway extending through a stop **182** located at the base of the heater fixture **39**. A puff-actuated sensor **45** suitable for use in the smoking system **21** is described in commonly assigned U.S. Pat. No. 5,060,671 and commonly assigned U.S. Pat. No. 5,388,594, the disclosures of which are incorporated herein by reference.

An indicator **51** is provided at a location along the exterior of the lighter **25**, preferably on the front housing portion **33**, to indicate the number of puffs available in the cigarette **23**. The indicator **51** preferably includes a seven segment liquid crystal display. In the preferred embodiment, the indicator **51** displays the digit "8" when a cigarette detector **53** detects the presence of a cigarette in the heater fixture **39**. The detector **53** can comprise a light sensor adjacent the open end of the cigarette receptacle **27** that detects when a beam of light is reflected off (or alternatively, transmitted through) an inserted cigarette **23**. Thereupon, the cigarette detector **53** provides a signal to the circuitry **41** which, in turn, responsively provides a signal to the indicator **51**. The display of the digit "8" on the indicator **51** reflects that the eight puffs provided on each cigarette **23** are available, i.e., none of the heater elements **37** have been activated to heat the cigarette **23**. After the cigarette **23** has been fully smoked, the indicator displays the digit "0". When the cigarette **23** is removed from the lighter **25**, the cigarette detector **53** no longer detects the presence of a cigarette **23** and the indicator **51** is turned off. The cigarette detector **53** is modulated so that it does not constantly emit a beam of light, which would otherwise create an unnecessary drain on the lithium ion power source **35***a*. In an alternative to displaying the remainder of the puff count, the detector display may instead be arranged to indicate whether the system is active or inactive ("on" or "off").

As one of several possible alternatives to using the above-noted cigarette detector **53**, a mechanical switch (not shown) may be provided to detect the presence or absence of a cigarette **23** and a reset button (not shown) may be provided for resetting the circuitry **41** when a new cigarette is inserted into the lighter, e.g., to cause the indicator **51** to display the digit "8", etc. Circuitry, puff-actuated sensors, and indicators useful with the smoking system **21** of the present invention are described in commonly assigned U.S. Pat. No. 5,060,671, U.S. Pat. No. 5,388,594 and the commonly assigned U.S. Pat. No. 5,505,214, all of which are incorporated by reference. Other alternatives for detecting the presence of a cigarette in the heater fixture **39** can include a metal detector that senses a metal foil or other metallic component within the cigarette.

In a preferred embodiment, the front housing portion **33** of the lighter **25** supports a substantially cylindrical heater fixture **39** which slidingly receives the cigarette **23**. The heater fixture **39** houses the heater elements **37** and is adapted to support an inserted cigarette **23** in a fixed relation to the heater elements **37** such that the heater elements **37** are positioned at a desired location alongside the cigarette **23**. The locations where each heater element **37** bears against (or is in thermal contact with) a fully inserted cigarette **23** is referred to herein as the heater footprint.

To assure consistent placement of the heating elements **37** relative to the cigarette **23** from cigarette to cigarette, the heater fixture **39** is provided with a stop **182** against which the cigarette is urged during its insertion into the lighter **25**. Other expedients to registering the cigarette **23** relative to the lighter **25** could be used instead.

The front housing portion **33** of the lighter **25** also includes electrical control circuitry **41** which delivers a predetermined amount of energy from the lithium ion power source **35***a* to the electrical resistance heating elements **37**. In the preferred embodiment, a heater fixture **39** includes eight circumferentially spaced-apart electrical resistance heating elements **37** which are concentrically aligned with the receptacle **27** so as to slidingly receive a cigarette **23**. Details of the construction and establishment of electrical connections to the heater fixture **39** are illustrated and described in commonly assigned U.S. Pat. Nos. 5,388,594, 5,505,214, and 5,591,368, all of which are incorporated herein by reference in their entireties.

Referring now to FIG. **2**, a preferred heater fixture **39** includes "singular serpentine" elements **37**, each of which is electrically connected at its opposite ends to a control circuit through leads **186** and **187**. Details concerning this heater fixture **37** are set forth in commonly assigned U.S. Pat. No. 5,388,594, incorporated herein by reference in its entirety. Additional heater fixtures **37** that can be used as part of the lighter **25** include those disclosed in commonly assigned U.S. Pat. Nos. 5,665,262 and 5,498,855 which are incorporated herein by reference.

Preferably, the heaters **37** are individually energized by the lithium ion power source **35***a* under the control of the circuitry **41** to heat the cigarette **23** preferably eight times at spaced locations about a periphery of the cigarette **23**. The heating renders eight puffs from the cigarette **23**, as is commonly achieved with the smoking of more traditional cigarettes. It may be preferred to activate more than one heater simultaneously for one or more or all of the puffs.

A common phenomenon associated with batteries is a voltage reduction as the battery is discharged. This occurs because the battery's voltage potential decreases as the battery is discharged. As a result, a fully charged or "fresh" battery is capable of delivering more power than a battery that has been substantially discharged.

It has been found that the amount of power delivered to the electrical resistance heating element **37** and the lighter **25** affects the consistency of the smoke delivered to a smoker. It is desirable to deliver a consistent quality of smoke with each puff on the cigarette and from cigarette to cigarette. A fully charged or "fresh" battery will deliver more power to the electrical resistance heating element **37** in the lighter **25** producing a high amount of heat. Conversely, a substantially discharged battery will deliver less power to the electrical resistance heating element **37** in the lighter **25** producing less heat. Thus, the amount of heat delivered by the electrical resistance heater reduces as the battery becomes discharged. This difference in the amount of heat produced by the electrical resistance heater during the life of the battery affects the consistency of the smoke produced from the heating. Since it is desirable to produce a consistent quality of smoke from puff to puff and cigarette to cigarette, it is desirable to deliver the same amount of energy to the electrical resistance heater from puff to puff and cigarette to cigarette.

Commonly assigned U.S. Pat. No. 6,040,560 describes a system and method for delivering the same amount of energy to the electrical resistance heater between chargings of the battery, and is hereby incorporated by reference in its entirety. The same amount of energy is delivered to the heater from the battery using a control circuit that modulates the flow of electrical energy to the electrical resistance heating element. The control circuit determines the amount of modulation by measuring the voltage and/or current of the battery. Consumers generally puff on a cigarette for about two seconds. Thus, the heaters need to supply heat to the cigarette during at least a portion of the two seconds of the puff period. When a puff is detected, the controller sends modulated electrical power to the electrical resistance heater. In order to deliver the same amount of energy to the electrical resistance heater from puff to puff, the controller determines the off-time between the electrical pulses to send to the electrical resistance heater based on a measured voltage and/or current of the battery. A battery that is fully charged or "fresh" will have greater voltage potential than a weaker battery that has been partially or substantially discharged. As a result, a fully charged or "fresh" battery will require the controller to have longer off-times and send fewer pulses of electrical energy to the heater in order to deliver the same amount of energy. Conversely, a weaker battery that has been partially or substantially discharged will require the controller to deliver more pulses of electrical energy with shorter off-times to the heater in order to deliver the same amount of energy to the heater. By adjusting the number of electrical pulses delivered to the heater, and the off-times between the electrical pulses, the same amount of energy can be delivered to the heater from puff to puff for different charged states of the battery.

FIG. **3** is a schematic diagram of an electrical circuit that can be used as the controller **41** in the lighter **25**. Eight individual heater elements **43** (not shown in FIG. **2**) are connected to a positive terminal of the power source **37** and to the negative terminal through corresponding field effect transistor (FET) heater switches **201** through **208**. Individual (or selected) ones of the heater switches **201** through **208** will be turned on and off under the control of logic circuit **195** through terminals **211** through **218**, respectively, during execution of a power cycle by the logic circuit **195**. The logic circuit **195** provides signals for activating and deactivating particular ones of the heater switches **201** through **208** to activate and deactivate the corresponding ones of the heaters.

The logic circuit **195** cooperates with the timing circuit **197** to precisely execute the activation and deactivation of each heater element **37** in accordance with a predetermined total cycle period and to precisely divide each total cycle period into a predetermined number of phases, with each phase having its own predetermined period of time. In the preferred embodiment, the total cycle period has been selected to be 1.6 seconds (so as to be less than the two second duration normally associated with a smoker's draw upon a cigarette, plus provision for margin). The total cycle is divided preferably into two phases: a first phase having a predetermined time period of one second and a second phase having a predetermined time period of 0.6 seconds. As discussed above, modulated pulses of electrical energy are delivered to the heater to deliver a precise amount of energy to the heater from puff to puff for the life of the battery. Established within the control circuit **41** is a capacity to execute a power cycle that precisely duplicates a preferred thermal interaction (thermal-histogram) between the respective heater element **37** and adjacent portions of the cigarette **23**. Additionally, once the preferred thermo-histogram is established, certain parameters (preferably, power cycles and off-times within each phase) are adjusted dynamically by the control circuit **41** so as to precisely duplicate the predetermined thermo-histogram with every power cycle throughout the range of voltages encompassed by the battery discharge cycle.

The puff-actuated sensor **45** supplies a signal to the electric circuit **195** that is indicative of smoker activation (i.e., a continuous drop in pressure of airflow over a sufficiently sustained period of time). The logic circuit **195** includes a routine for distinguishing between minor air pressure variations and more sustained draws on the cigarette to avoid inadvertent activation of heater elements in response to an errant signal from the puff-actuated sensor **45**. The puff-actuated sensor **45** may include a piezo resistive pressure sensor or an optical flap sensor that is used to drive an operational amplifier, the output of which is in turn used to supply a logic signal to the logic circuit **195**.

The light sensor **53** located adjacent the stop **182** supplies a signal to the logic circuit **195** that is indicative of insertion of a cigarette **23** in the lighter **25** to a proper depth (i.e., a cigarette is within several millimeters of the light sensor so as to be detected by a reflected light beam).

In order to conserve energy, it is preferred that the puff-actuated sensor **45** and the light sensor **53** be cycled on and off at low duty cycles (e.g., from about 2 to 10 percent of a duty cycle). For example, it is preferred that the puff actuation sensor **45** be turned on for a one millisecond duration for every ten milliseconds of the duty cycle. If, for example, the puff-actuated sensor **45** detects pressure drop or airflow indicative of draw on a cigarette during four consecutive pulses (i.e., over a 40 millisecond period), the puff-actuated sensor sends a signal through a terminal **221** to the logic circuit **195**. The logic circuit **195** then sends a signal to an appropriate one of the terminals **211** through **218** to turn on an appropriate one of the FET heater switches **201** through **208**.

Similarly, the light sensor **53** is preferably turned on for a one millisecond duration for every ten milliseconds. If, for example, the light sensor **53** detects four consecutive reflected pulses, indicating the presence of a cigarette **23** in the lighter **25**, the light sensor sends a signal through terminal **223** to the logic circuit **195**. The logic circuit **195** then sends a signal through terminal **225** to the puff-actuated sensor **45** to turn on the puff-actuated sensor. The logic circuit **195** also sends a signal through terminal **227** to the indicator **51** to turn it on. The above-noted modulation techniques reduce the time average current required by the puff-actuation sensor **45** and the light sensor **53**, and thus extend the life of the lithium ion power source **37**.

The electric circuit **195** can include a PROM (programmable read-only memory) **300**, which may include preferably at least two databases or look-up tables **302** and **304** and optionally, a third database (look-up table) **306**. Each of the look-up tables **302**, **304** (and optionally **306**) converts a signal indicative of battery voltage to a signal indicative of the power cycle (for the first phase and for the second phase) to be used in execution of the respective phases of the power cycle.

Upon initiation of a power cycle, the logic circuit receives a signal indicative of lithium ion power source voltage and/or current, and then references the voltage and/or current reading to the first look-up table **302** to establish a duty cycle for the initiation of the first phase of the power cycle. The first phase is continued until the timing network **197** provides a signal indicating that the predetermined time period for the first phase has elapsed, whereupon the logic circuit **195** references the lithium ion power source voltage and/or current in the second look-up table **304** and establishes a duty cycle for the initiation for the second phase. The second phase is continued until the timing network **197** provides a signal indicating that the predetermined time period for the second phase has elapsed, whereupon the timing network **197** provides a shut-off signal to the logic circuit **195** at the terminal **229**. Optionally, the logic circuit **195** could initiate a third phase and establish a third duty cycle, and a shut-off signal would not be generated until the predetermined period of time for the third phase has elapsed. The present invention could be practiced with additional phases or other variations of the power cycle.

Although the present invention can be practiced by using the look-up tables during an initial portion of each phase to establish a duty cycle to be applied throughout the substantial entirety of each phase, the preferred practice is to have the logic circuit **195** configured to continuously reference the lithium ion power source voltage and/or current together with the respective look-up tables **302**, **303** and **306** so as to dynamically adjust the value set for the duty cycle in response to fluctuations in lithium ion power source voltage as the control circuit progresses through each phase. Such practice can provide a more precise repetition of the desired thermo-histogram.

The timing network **197** is also preferably adapted to prevent actuation of one heater element **43** to the next as the lithium ion power source discharges. Other timing network circuit configurations may also be used, such as those described in commonly assigned U.S. Pat. No. 5,505,214, the disclosure of which is incorporated herein by reference.

In an exemplary embodiment of smoking a cigarette, a cigarette **23** is inserted in the lighter **25** and the presence of the cigarette is detected by a sensor such as a metal detector effective for sensing the presence of a metal foil in the cigarette, or the light sensor **53**. Light sensor **53** sends a signal to the logic circuit **195** through terminal **223**. The logic circuit **195** ascertains whether the lithium ion power source **37** is charged or whether the immediate voltage is below an acceptable minimum. If, after insertion of the cigarette **23** in the lighter **25**, the logic circuit **195** detects that the voltage of the lithium ion power source is too low, the indicator **51** blinks and further operation of the lighter will be disabled until the lithium ion power source is recharged. Voltage of the lithium ion power source **37** is also monitored during activation of the heater elements **37** and the activation of a heating element is interrupted if the voltage drops below a predetermined value.

When the logic circuit **195** receives a signal through terminal **221** from the puff-actuated sensor **45** that a sustained pressure drop or airflow has been detected, the logic circuit locks out the light sensor **53** during puffing to conserve power. The logic circuit **195** sends a signal through terminal **231** to the timer network **197** to activate the timer network, which then begins to function phase by phase in the manner previously described. The logic circuit **195** also determines, by a down count routine, which one of the eight heater elements is due to be heated and sends a signal through an appropriate terminal **211** through **218** to turn on an appropriate one of the FET heater switches **201** through **208**. The appropriate heater stays on while the timer runs.

When the timer network **197** sends a signal through terminal **229** to the logic circuit **195** indicating that the timer has timed out, the particular FET heater switch **211** through **218** is turned off, thereby cutting off power to the heating element. The logic circuit **195** also down counts and sends a signal to the indicator **51** through terminal **227** so that the indicator will display that one less puff is remaining (i.e., "7", after the first puff). When the smoker next puffs on the cigarette **23**, the logic circuit **195** will turn on another one of the predetermined FET heater switches **211** through **218**, thereby supplying power to another predetermined one of the heater elements. The process will be repeated until the indicator **51** displays "0", meaning that there are no more puffs remaining on the cigarette **23**. When the cigarette **23** is removed from the lighter **25**, the light sensor **53** indicates that the cigarette is not present, and the logic circuit **195** is reset.

Other features, such as those described in U.S. Pat. No. 5,505,214, which is incorporated by reference, may be incorporated in the control circuit **41** instead of, or in addition to, the features described above. For example, if desired, various disabling features may be provided. One type of disabling feature includes timing circuitry (not shown) to prevent successive puffs from occurring too close together, so that the lithium ion power source **35***a* has time to recover. Another disabling feature includes means for disabling the lighter **25** if an unauthorized product is inserted in the heater fixture **39**. For example, the cigarette **23** might be provided with an identifying characteristic that the lighter **25** must recognize before the heating elements **37** are energized.

The lithium ion power source **35***a* is preferably one or more lithium ion batteries. Manufacturers of lithium ion batteries recommend that the batteries not be discharged at greater than 1 C wherein "C" is the numerical equivalent to the discharge capacity of the battery in milliamps (mA). Thus, for a 1000 mAh battery, the battery should not be discharged at a current greater than 1000 milliamps (mA) or 1 amp. This is because discharging the battery at rates greater than 1 C could cause the battery to become hot, catch fire, or explode. The electrical resistance heaters of the present invention draw peak discharge currents in the range of 15 to 30 C. This is well above industry norms of discharge rates of between 2 to 3 C for consumer products that are considered to require high discharge rates. Although lithium ion batteries are not intended to deliver the discharge rates required for electrical smoking systems, the electrically heated smoking device of the present invention provides an arrangement wherein lithium ion batteries can be used safely and effectively.

Lithium ion batteries have higher voltages, typically, a usable range of between 4.2 and 3.0 volts, than other rechargeable batteries, meaning that a single lithium ion battery cell has a voltage roughly equivalent to three nickel cadmium batteries connected in series. The smoking system according to the invention is operated such that the electrical resistance heaters become hot in a very short period of time after a smoker begins puffing on the cigarette. For this near instantaneous heating to occur, a voltage of between 3 and 20, preferably 3 and 12, volts is required. Since lithium ion batteries have higher voltages than other rechargeable batteries, fewer lithium ion cells are required to meet the required range of voltages.

Even though the electric resistance heaters of the smoking system draw current of as much as 30 C which is far in excess of the 1 CmA recommended by lithium ion battery manufacturers, lithium ion batteries have proven to be effective to supply power to the electric resistance heater. This is because the required current is drawn from the lithium ion battery for a short period of time on the order of approximately one to two seconds, preferably 1.6 seconds, which is too short of a duration to cause the battery to lose so much voltage that it can no longer generate sufficient power for good flavor generation, or become hot, catch fire or explode.

Manufacturers of lithium ion batteries provide circuitry within the battery to prevent overdischarge and overcharging of the lithium ion battery. Since the electric resistance heaters of the smoking system draw current that is as much as 20 times, or more, than the manufacturer's recommended discharge rate, typically 1 C, the manufacturer's over discharge protection circuitry would be triggered when used with the electric resistance heaters of the smoking system. In order to use the lithium ion batteries with the electrical resistance heaters of the smoking system, the parameters of the over discharge protection circuitry are preferably adjusted upward.

FIG. **4** illustrates an exemplary lithium ion battery and protection circuit usable in the present invention. As illustrated, the battery pack **400** includes three lithium ion battery cells **B1**–**B3** connected in series and circuitry to prevent the battery from overdischarging and overcharging to thereby avoid conditions may cause the battery to get hot, catch fire, or explode.

The lithium ion battery cells can have an electrical storage capacity of between 100 and 2000 mAh, preferably between 200 and 1500 mAh, and more preferably between 250 and 1000 mAh. Current discharge from each of the lithium ion batteries cells **B1**–**B3** flows through a respective polyswitch **PSW1**–**PSW3**. The polyswitches **PSW1**–**PSW3** can be, for example, model number LR4-450 available from the Raychem Circuit Protection Division of the Tyco Electronics Corporation located in Menlo Park, Calif. The polyswitches **PSW1**–**PSW3** cut off current flow when the current flowing through the polyswitch rises above a predetermined threshold level, e.g., greater than 50 C, preferably greater than 30 C, and more preferably greater than 20 C. Unlike a fuse, the polyswitches will reconnect current flow after a period of time has elapsed. Polyswitches also provide the advantage of sensing temperatures and shutting off if temperatures reach too high a level. Each of the lithium ion battery cells can be connected to a respective series RC circuit having a resistor **R1**–**R3** and a capacitor **C1**–**C3**. The RC circuits isolate the respective lithium ion battery cell from the rest of the circuit in the battery pack **400**.

An Application Specific Integrated Circuit (ASIC) **406** (or preprogrammed microcontroller or microprocessor) can be used to monitor the voltage of each of the lithium ion battery cells **B1**–**B3**. A signal indicative of the voltage of the first lithium ion battery cell **B1** is supplied to the ASIC **406** via terminal V_{C1}. A signal indicative of the voltage of the second lithium ion battery cell **B2** is supplied to terminal V_{C2}. A signal indicative of the voltage of the third lithium ion battery cell **B3** is supplied to terminal V_{SS} of ASIC **406**. Power is supplied to the ASIC **406** via terminal V_{CC}. Switches **Q1** and **Q2** are activated by the ASIC **406** via terminals DOP and COP. Switch **Q1** includes a pair of field effect transistors (FET) **401** and **402**. Similarly switch **Q2** also includes a pair of field effect transistors (FET) **403** and **404**. The pair of field effect transistors used in each switch **Q1** and **Q2** permits the requisite amount of current to flow through switch **Q1** or **Q2** to the electrical resistance heating element without damaging the field effect transistors. When the ASIC **406** detects a discharge voltage below a predetermined threshold limit, e.g., 2.3 volts, the ASIC **406**, via terminal DOP, cuts off power supplied to the gates of field effect transistors **401** and **402** of switch **Q1** to stop current from flowing from the battery **400**. When the ASIC **406** detects that the voltage of the lithium ion battery cells is above a predetermined threshold level, e.g., 4.3 volts, the ASIC **406**, via terminal COP, cuts off the supply of power to the gates of field effect transistors **403** and **404** of switch **Q2** disconnecting flow of current into the battery pack **400**.

Thus, in the exemplary embodiment the current flow capacity of the polyswitches has been increased to a level sufficient to supply the greater current flow required by the electrical resistance heating element. In addition, switches

Q1 and Q2 include two FETs so that the requisite current required by the electrical resistance heating elements can flow through switches Q1 and Q2 without damaging the FETs.

While an exemplary battery pack **400** of the present invention has been described, it will be apparent to one skilled in the art to use any desired number of lithium ion batteries, e.g., one or more lithium ion battery cells, or alternative arrangements of electrical circuitry for protecting a lithium ion battery cell. It will also be appreciated by those skilled in the art that switches Q1 and Q2 could be made from any electrically controllable switches, e.g., relays. Thus, any combination of lithium ion battery cells and electrical circuitry are considered to be within the scope of the present invention.

The invention has been described with reference to a particular embodiment. However, it will be readily apparent to those skilled in the art that it is possible to embody the invention in specific forms other than those of the preferred embodiments described herein. This may be done without departing from the spirit of the invention. The preferred embodiments are merely illustrative and should not be considered restrictive in any way. The scope of the invention is given by the appended claims, rather than the preceding description, and all variations and equivalents which fall within the range of the claims are intended to be embraced therein.

What is claimed is:

1. An electrically heated smoking system comprising:

at least one electrical resistance heating element;

a lithium ion power source electrically connected to the at least one electrical resistance heating element; and

a controller to control a flow of modulated pulses of electrical power from the lithium ion power source to the at least one electrical resistance heating element to prevent damage to the lithium ion power source.

2. The electrically heated smoking system of claim **1**, wherein the lithium ion power source comprises a lithium ion battery cell.

3. The electrically heated smoking system of claim **2**, wherein the lithium ion battery cell has a maximum voltage greater than 4 volts.

4. The electrically heated smoking system of claim **2**, wherein the lithium ion battery cell has a discharge capacity of 250 to 2000 mAh.

5. The electrically heated smoking system of claim **2**, wherein the lithium ion battery cell has a peak discharge current of 15 to 30 times an ampere hour capacity of the lithium ion battery cell.

6. The electrically heated smoking system of claim **2**, wherein the lithium ion battery cell has an average discharge current of 10 to 20 times an ampere hour capacity of the lithium ion battery cell.

7. The electrically heated smoking system of claim **2**, wherein the lithium ion power source comprises at least one lithium ion battery cell and circuitry to stop flow of current if the at least one lithium ion battery cell is short circuited.

8. The electrically heated smoking system of claim **7**, wherein the lithium ion power source comprises multiple lithium ion battery cells.

9. The electrically heated smoking system of claim **8**, wherein the lithium ion power source comprises three lithium ion battery cells.

10. The electrically heated smoking system of claim **8**, wherein the multiple lithium ion battery cells are electrically connected together in series such that the multiple lithium ion battery cells deliver a voltage to the at least one electrical heating element that is equal to a sum of a voltage of each of the lithium ion battery cells.

11. The electrically heated smoking system of claim **8**, wherein each of the multiple lithium ion battery cells has a maximum voltage greater than 4 volts.

12. The electrically heated smoking system of claim **8**, wherein each of the multiple lithium ion battery cells has a discharge capacity of 250 to 2000 mAh.

13. The electrically heated smoking system of claim **8**, wherein each of the multiple lithium ion battery cells has a peak discharge current of 15 to 30 times an ampere hour capacity of each of the lithium ion battery cells.

14. The electrically heated smoking system of claim **8**, wherein each of the multiple lithium ion battery cells has an average discharge current of 10 to 20 times an ampere hour capacity of each of the lithium ion battery cells.

15. The electrically heated smoking system of claim **7**, wherein the circuitry monitors charging of the at least one lithium ion battery cell to prevent over heating and over charging of the at least one lithium ion battery cell.

16. The electrically heated smoking system of claim **1**, wherein the at least one electrical resistance heating element comprises a plurality of electrical resistance heating elements each of which is disposed proximate to the cigarette and individually activated to heat a selected portion of the cigarette.

17. A method for smoking a cigarette with an electrically heated smoking system, the method comprising:

providing electrical power to at least one electrical heating element from a lithium ion power source, the at least one electrical heating element being arranged to heat at least a portion of a cigarette sufficiently to generate tobacco smoke; and

controlling the electrical power provided to the at least one electrical heating element by sending modulated pulses of electrical power from the lithium ion power source to the at least one electrical heating element thereby preventing damage to the lithium ion power source.

18. The method of claim **17**, wherein the lithium ion power source comprises at least one lithium ion battery cell which supplies electrical current to the at least one electrical heating element.

19. The method of claim **18**, wherein the lithium ion battery cell has a discharge capacity of 250 to 2000 mAh which supplies electrical current to the at least one electrical heating element.

20. The method of claim **18**, wherein the lithium ion battery cell has an average discharge current of 10 to 20 times an ampere hour storage capacity of the lithium ion battery cell which supplies electrical current to the at least one electrical heating element.

21. The method of claim **18**, wherein the lithium ion battery cell delivers a peak current of 15 to 30 times an ampere hour storage capacity of the lithium ion battery cell to the at least one electrical heating element which supplies electrical current to the at least one electrical heating element.

22. The method of claim **18**, wherein the lithium ion battery cell has a maximum voltage greater than 4 volts.

23. The method of claim **18**, wherein the lithium ion battery cell has a discharge capacity of 250 to 2000 mAh.

24. The method of claim **17**, wherein the at least one electrical resistance heating element comprises a plurality of electrical resistance heating elements each of which is disposed proximate to the cigarette to heat selected portions of the cigarette.

25. The method of claim **17**, wherein the lithium ion power source includes at least one lithium ion battery cell and circuitry to stop flow of current if the at least one lithium ion battery cell is short circuited.

* * * * *